PHYS/BIOL 497, Systems Biology and Networks

Spring 2012   T Th 9:45 - 11:00 am, 104 Osmond Lab
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Many complex systems are difficult to describe and understand because they are composed of large numbers of elements interacting in a non-ordered way. A good example is cellular biology: diverse cellular components (genes, proteins, enzymes) participate in various reactions and regulatory interactions, forming a robust system. A very useful representation of complex systems is given by graphs (or networks), where we denote the components with nodes and their interactions by edges. The properties of these interaction graphs can then be analyzed by computational methods and this information can lead to important conclusions about the possible dynamical behaviors of the system.

The course will cover examples of network analysis and modeling in biology and medicine, including methods of regulatory network inference from gene expression data; analysis of molecular networks: gene regulatory networks, signal transduction networks, metabolic networks; modeling the dynamics of reaction networks, signal transduction networks, gene regulatory networks. After taking this course students will be able to gather information to construct a network model corresponding to a biological system, to use graph theoretical measures to describe this network, and to use mathematical or computational methods to model the dynamic processes that take place in this system.

Textbook: 'Computational Modeling of Gene Regulatory Networks - a primer' by Hamid Bolouri (Imperial College Press, 2008). This will be supplemented by various recent review articles (copies will be provided).

The **prerequisite** for this course is basic calculus. Background information and handouts on mathematical methods will be provided.

Grades will be based on homework assignments (40%), presentation of a research article from the literature (20%), and a term paper (40%). Weekly homework will include exercises and critical reading assignments. There will be 8 homework assignments, graded on a 1 to 10 basis. Participants will choose a research article from a list of suggestions and give a 10 minute analysis of it midway through the semester. Term paper topics will be selected from a list of suggestions or can be based on the research interests of the participants. A paper outline will be due at the end of March. There will be a 15 min presentation of the term paper during the last week of classes. The final papers will be due on May 1, at 7 pm.

Main topics covered:
1. elements of graph theory: node degree, distances between nodes, node betweenness, subgraphs, directed graphs
2. graph algorithms and graph analysis/visualization software
3. graph analysis of cellular networks: gene regulatory networks, signal transduction networks, metabolic networks
4. graph models and theory: lattices, random graphs, small-world networks, scale-free networks, evolving networks

5. network resilience and vulnerability
6. modeling the dynamics of reaction networks and of signal transduction networks
7. modeling the dynamics of gene regulatory networks - continuous, discrete and stochastic.
8. inference of gene regulatory networks from gene expression data - continuous, Boolean and Bayesian methods

Week	Date	Tuesday	Thursday
1	1/9	Introduction	Definition of molecular networks
2	1/16	Basic graph measures HW 1 due	Basic graph measures
3	1/23	Software for network analysis HW 2 due	Properties shared by various networks
4	1/30	Molecular networks as models HW 3 due	Random graph theory
5	2/6	Network models HW 4 due	Network resilience
6	2/13	Resilience of biological networks HW 5 due	Dynamic modeling concepts
7	2/20	Mass action kinetics Paper selection due	Continuous and deterministic modeling
8	2/27	Paper presentations	Paper presentations
9	3/5	Spring break	Spring break
10	3/12	Continuous and deterministic modeling HW 6 due	Parameter sensitivity analysis
11	3/19	Discrete dynamic modeling HW 7 due	Discrete dynamic modeling
12	3/26	Examples of modeling gene regulatory networks Topic selection due	Examples of modeling signal transduction networks
13	4/2	Stochastic modeling HW 8 due	Bayesian networks
14	4/9	Network inference Preliminary paper due	Network inference
15	4/16	Examples from the current literature	Examples from the current literature
16	4/23	Project presentations	Project presentations